Connector loss budgeting methodology for parallel multimode PMDs

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Supporters and contributors

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Introduction

- 802.3ba is developing a standard for 100G and 40G Ethernet, including parallel fibre MMF links (Nx10G per fibre)
- This presentation addresses a connector loss budget approach based on statistical treatment of connector loss, drawing on work used to develop 10GBASE-S and 10GBASE-LRM specifications

Aims

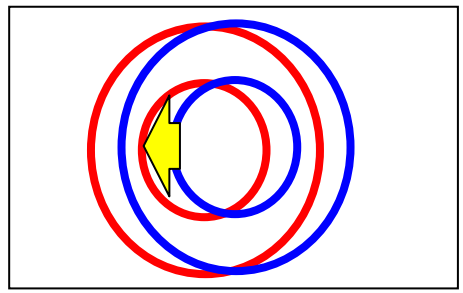
- Support 2 connections worst case
- Show that up to 4 connectors can be supported when losses are calculated by a careful statistical analysis

Established standards

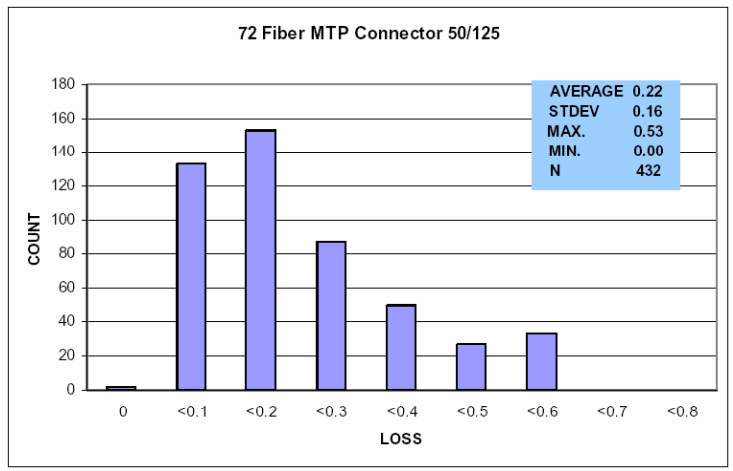
- ISO 11801-1995 cabling standard specifies a worst case individual connector loss (OFL) of 0.75 dB for MMF links
- Total connector loss allocation for Gigabit Ethernet is 1.5 dB (2 worst case 0.75 dB loss connectors)
- Gigabit Ethernet states that if the link contains 3 connectors then the worst case loss must be reduced to 0.5 dB per connector

Parallel connector loss statistics

- loss dominated by fibre to fibre offset
  - light spills out of side of the fibre
    - Rayleigh distribution of offsets
      - Pepeljugoski et al (ref 1)
      - Brunsting et al (ref 2)



- leads to ~Rayleigh distribution of connector loss

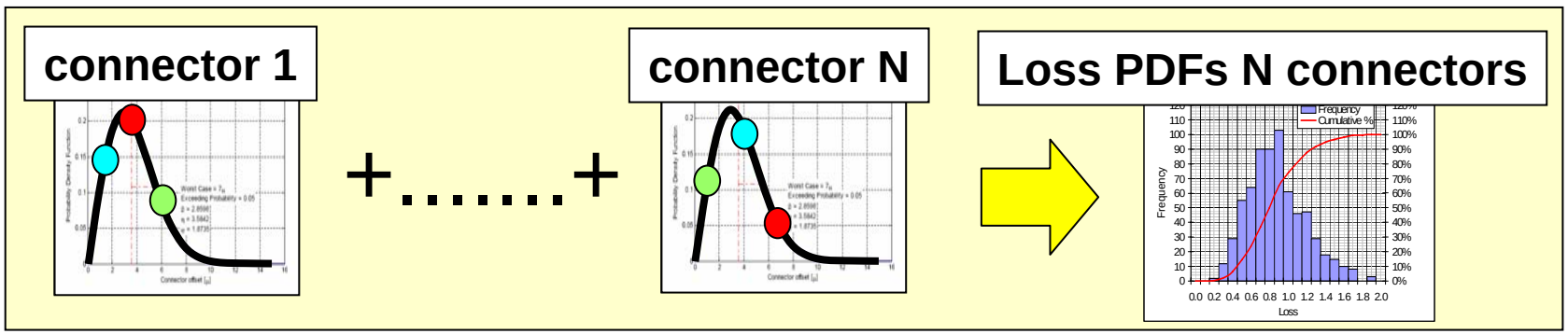


Computing total loss for 1 to 4 connectors

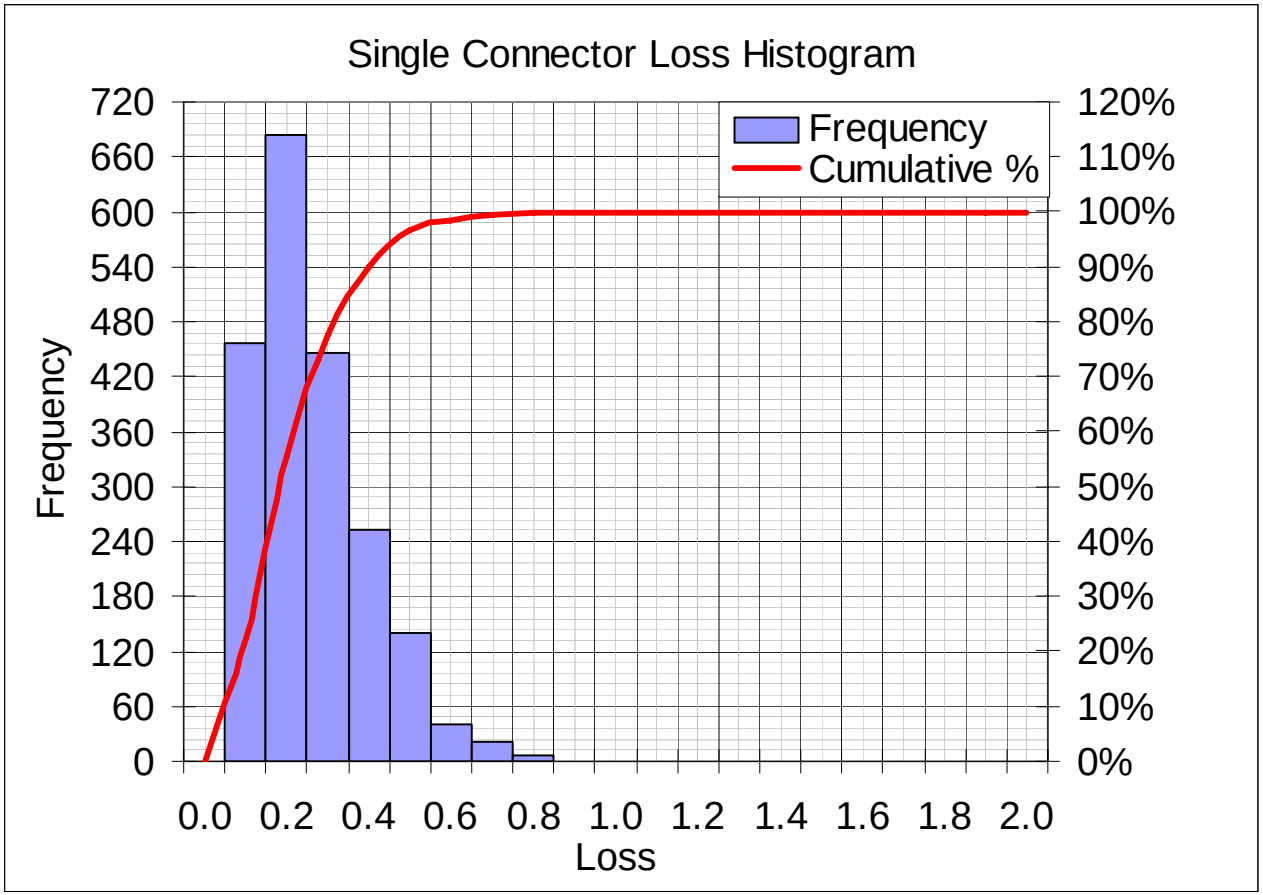
- Monte Carlo spreadsheet model of 2048 connectors with Rayleigh probability density function (PDF) of loss (following 12-parallel-fibre connector data in ref's 3a,b,c)
  - single connector: mean 0.22 dB , σ = 0.134 dB, 95% <0.5 dB

- Histograms of total loss for 2000 single connectors, and 500 to 1000 combinations of 2, 3, and 4 connectors plotted

  (Similar approach used in 802.3aq 10GBASE-LRM for link model)

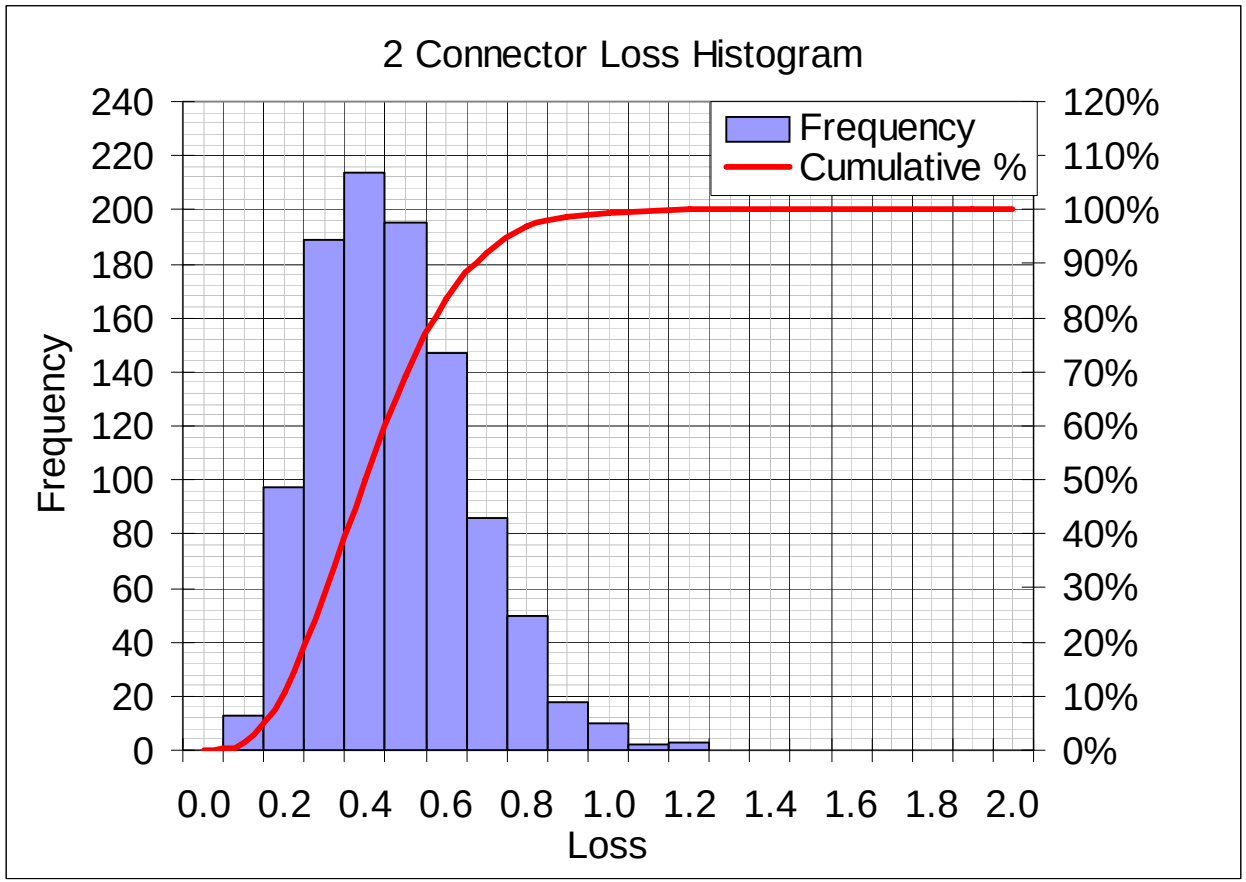


Single connector loss pdf



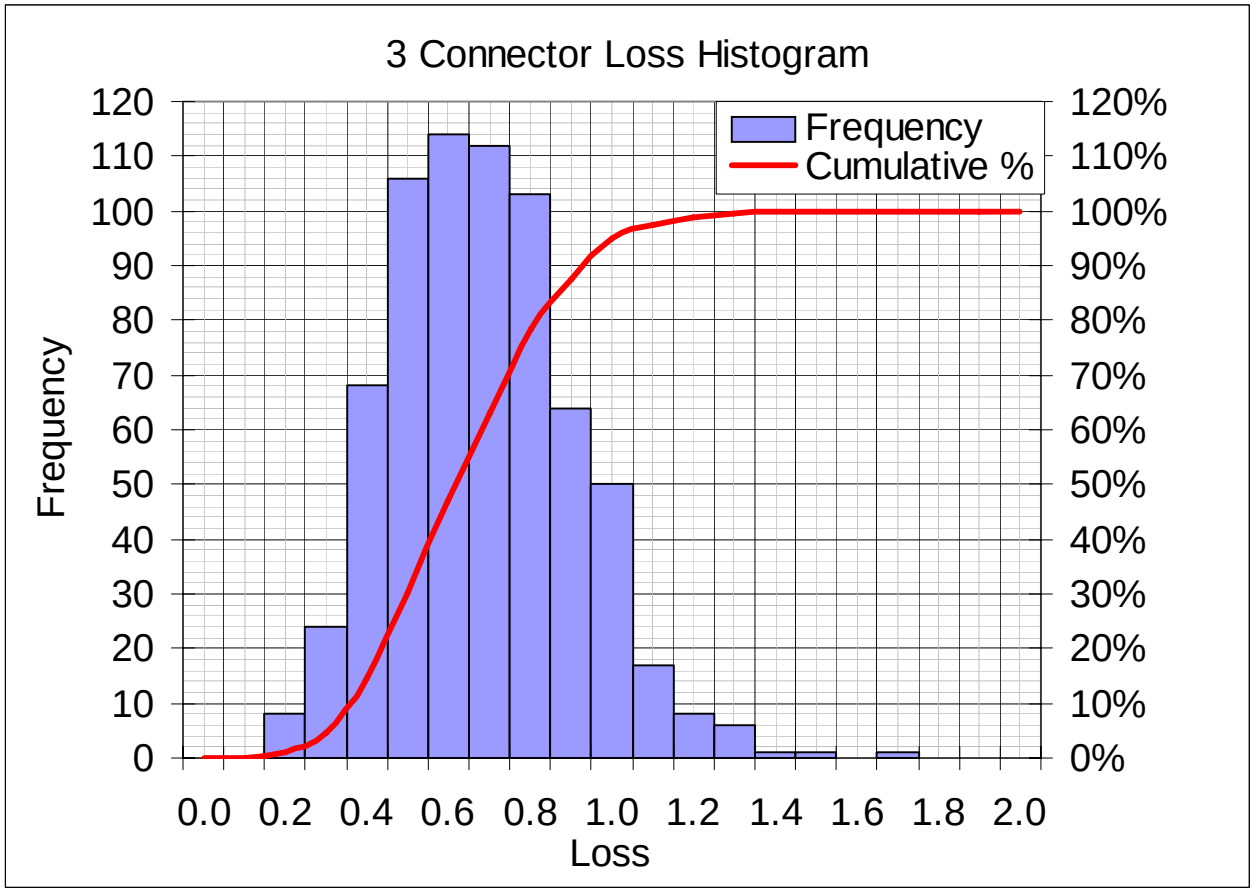
- mean loss=0.22 dB, s.d.=0.134 dB
- 95%<0.5dB loss, 99.7%<0.75dB

2 connectors loss pdf



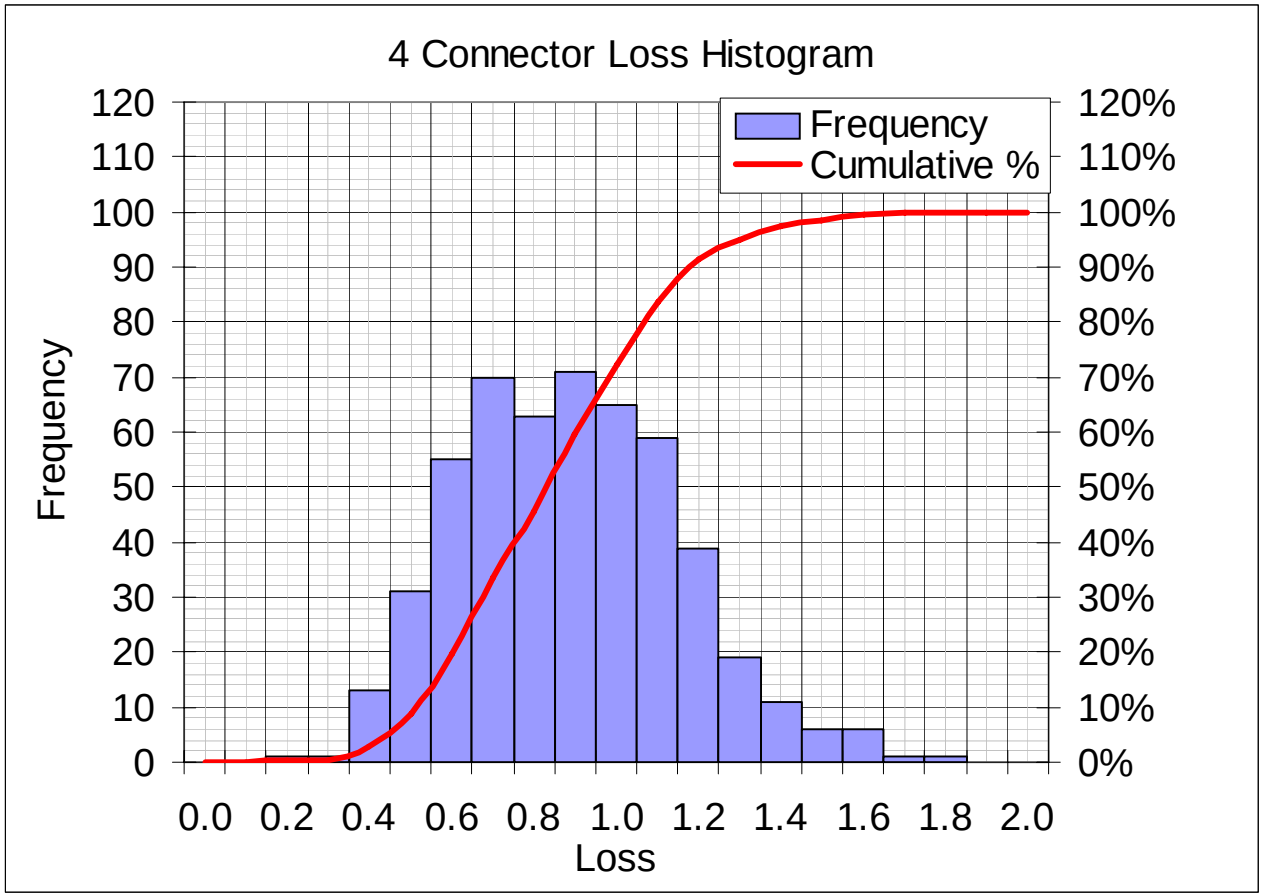
- mean loss=0.421dB, s.d.=0.187dB
- 95%<0.8dB, 100%<1.2dB loss

3 connectors loss pdf



- mean loss=0.631 dB, s.d.=0.221 dB
- 95%<1.0dB loss, 99.9%<1.5 dB loss

4 connectors loss pdf



- mean loss=0.842 dB, s.d.=0.264 dB
- 95%<1.3dB loss, 98.4%<1.5 dB loss

Summary table with commercial parallel fibre connectors for comparison

	Gigabit Ethernet	Computed loss (based on ref's 1,2,3)	Probability
1 connector loss	0.75 dB max	0.5 dB (0.75 dB)	95% (99.7%)
2 connector loss	1.5 dB max	1.5 dB	100%
3 connector loss	1.5 dB max	1.5 dB	99.9%
4 connector loss		1.5 dB	98.4%
Vendor a 12 fiber connector	data sheet: max 0.5 dB, typ 0.1 dB		
Vendor b 12 fiber connector	data sheet: max 0.5 dB, typ 0.2 dB		
Vendor c 72 fiber connector (white paper)	mean 0.22 dB, s.d. 0.16 dB (95%<0.5dB)		

Summary and Recommendation

- Connector loss probabilities have been calculated, based on Rayleigh statistics and modern multi-fiber connector specifications (refs.1,2,3). Results show:
  - 2 connectors with total loss <1.5dB at 100% probability
    - cf Gigabit Ethernet 2 x worst case 0.75dB connections
  - 3 connectors with total loss <1.5dB at 99.9% probability
    - cf Gigabit Ethernet 3 x max 0.5dB connectors
  - 4 connectors with total loss <1.5dB at 98.4% probability
    - *Modelled losses are probably pessimistic compared to latest specifications for parallel fibre connector assemblies*
- Recommendation:
  - Allocate 1.5 dB maximum total connector loss for parallel MMF PMDs

References

1) Pepeljugoski et al, "Development of System Specification for Laser Optimized 50-um Multimode Fiber for Multigigabit Short-Wavelength LANs", IEEE J. Lightwave Technology 21(5), pp1256 ff, May 2003
   - http://www.corning.com/docs/opticalfiber/r4254.pdf
2) Brunsting & Pimpinella,"Lateral offsets for multimode fiber (MMF) connectors", presented to 802.3aq Channel ad hoc, task 2, 15th Dec 2004.
   - http://ieee802.org/3/10GMMFSG/email/ppt00030.ppt
   - http://ieee802.org/3/10GMMFSG/email/ppt00031.ppt
3) Commercial multifibre connector datasheets and white papers
   a) http://www.furukawaamerica.com/resource/MT_Ferrules_0307.pdf
   b) http://www.usconec.com/pages/products/ferrules/mt/mtfrm.html
   c) http://www.tycoelectronics.com/documentation/whitepapers/pdf/eDigest-Advances_In_High_Density_Optical_Interconnects.pdf

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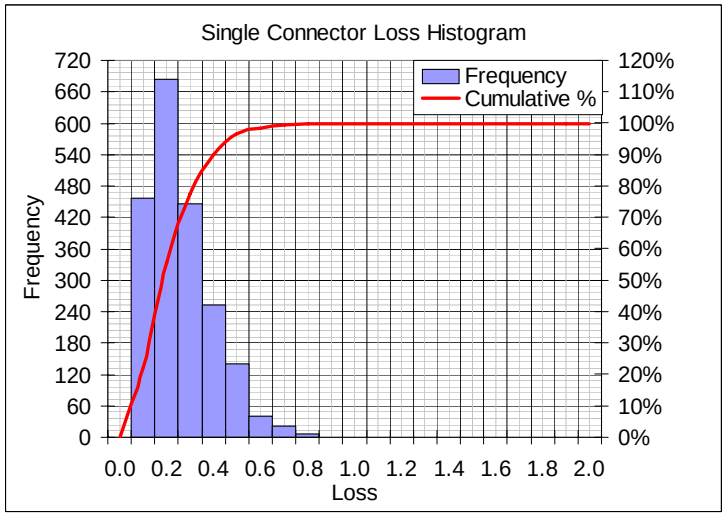
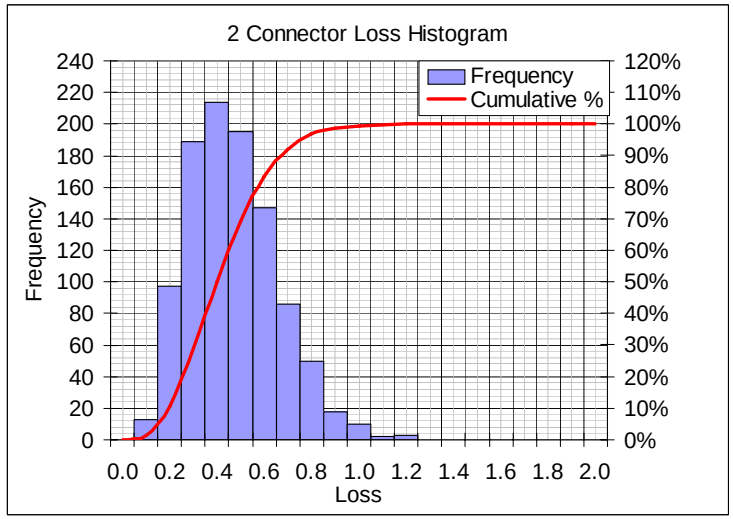
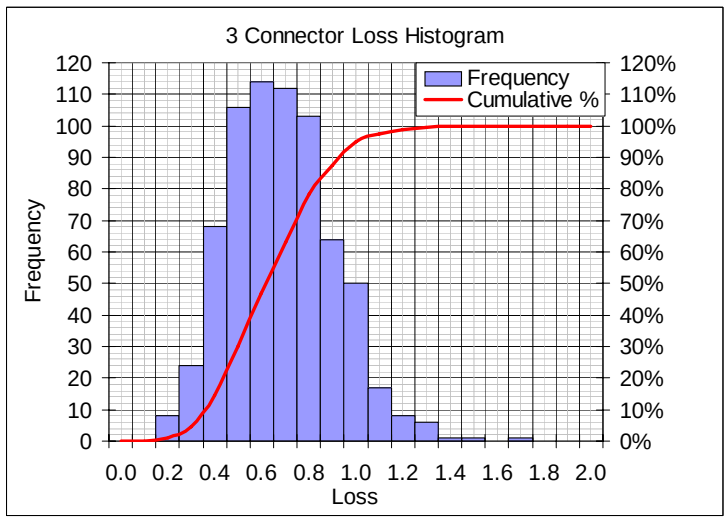
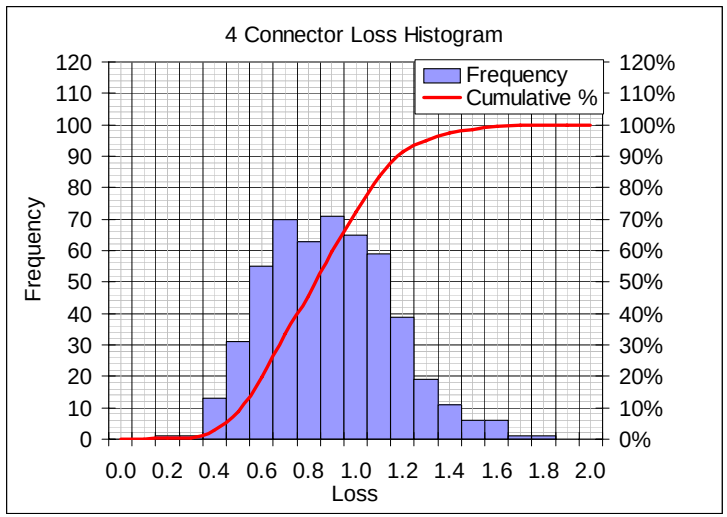
Computed multiple connector loss



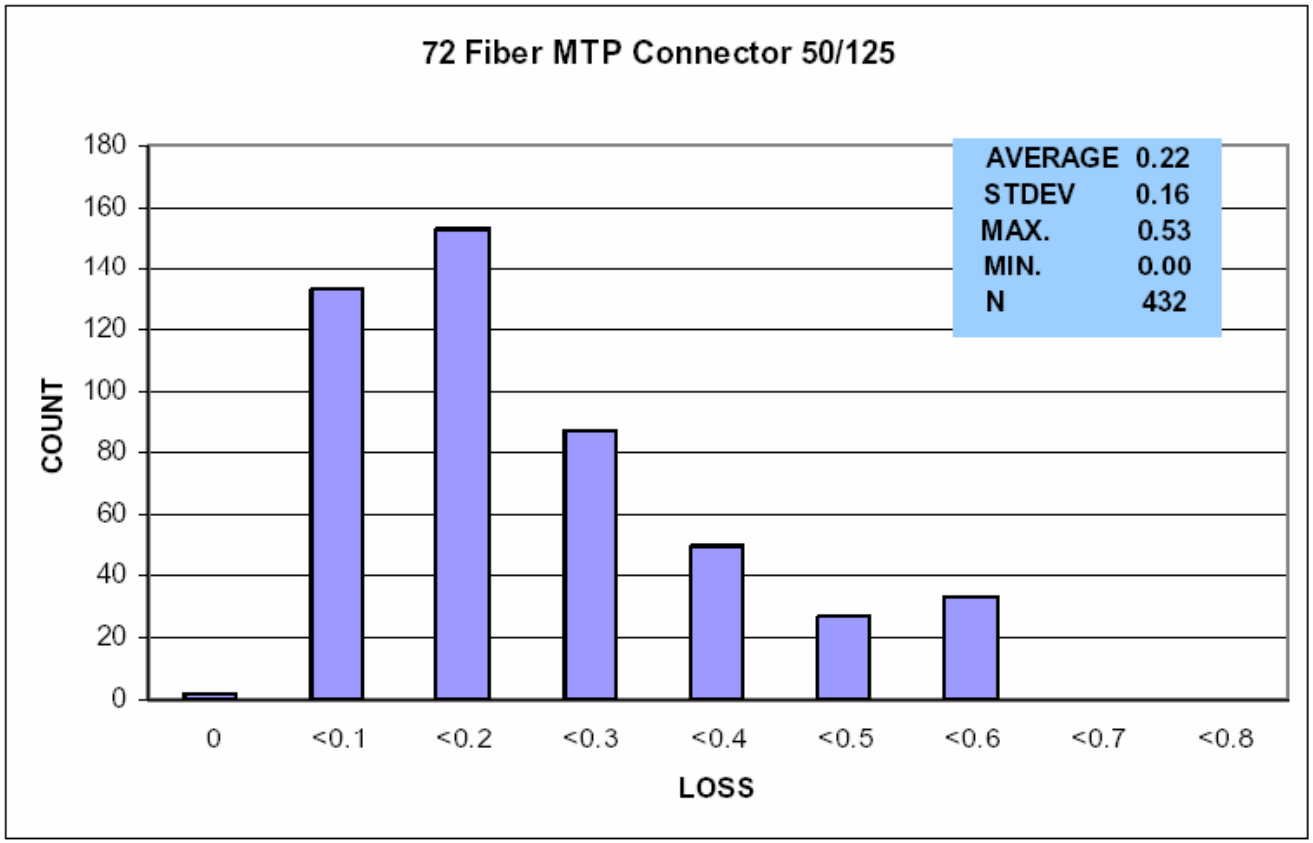






- 1 to 4 connectors - loss PDFs at a glance

Tyco white paper (ref.3c)



- http://www.tycoelectronics.com/documentation/whitepapers/pdf/eDigest-Advances_In_High_Density_Optical_Interconnects.pdf